1.2 OVERVIEW OF PWB INDUSTRY

1.2.1 Types of Printed Wiring Boards

PWBs may be categorized in several ways, including by layer counts or by substrate. Layer counts are the number of circuit layers present on a single PWB, giving an indication of the overall complexity of the PWB. The most common categories of layer counts are multi-layer, double-sided, and single-sided PWBs. Multi-layer PWBs contain more than two layers of circuitry, with at least one layer imbedded in the substrate beneath the surface of the board. Multi-layer boards may consist of 20 or more interconnected layers, but four, six, and eight layer boards are more common. Double-sided boards have circuitry on both sides of a board, resulting in two interconnected layers, while single-sided PWBs have only one layer of circuitry. Double-sided and single-sided PWBs are generally easier to produce than multi-layer boards (EPA, 1995e).

PWB substrates, or base material types, fall into three basic categories: rigid PWBs, flexible circuits, and rigid-flex combinations. Rigid multi-layer PWBs dominate the domestic production value of all PWBs (see Section 1.2.2, below) and are the focus of this CTSA.

Rigid PWBs typically are constructed of glass-reinforced epoxy-resin systems that produce a board less than 0.1" thick. The most common rigid PWB thickness is 0.062", but there is a trend toward thinner PWBs. Flexible circuits (also called flex circuits) are manufactured on polyamide and polyester substrates that remain flexible at finished thicknesses. Ribbon cables are common flexible circuits. Rigid-flex PWBs are essentially combinations or assemblies of rigid and flexible PWBs. They may consist of one or more rigid PWBs that have one or more flexible circuits laminated to them during the manufacturing process. Three-dimensional circuit assemblies can be created with rigid-flex combinations (EPA, 1995e).

1.2.2 Industry Profile

The total world market for PWBs is about $21 billion, with U.S. production accounting for about one quarter (more than $5 billion). The U.S.-dominated world market for PWBs eroded from 1980 to 1990, but has come back slightly in recent years. The PWB industry is characterized by highly competitive global sourcing with low profit margins (EPA, 1995e).

The U.S. has approximately 700 to 750 independent PWB manufacturing plants and about 70 captive facilities (e.g., original equipment manufacturers [OEMs] that make PWBs for use internally in their own electronic products) (EPA, 1995e). California, Minnesota, Texas, Illinois, Massachusetts, and Arizona have the highest number of PWB manufacturing plants, but there are PWB manufacturing facilities in virtually all 50 states and territories. More than 75 percent of U.S.-made PWBs are produced by independent shops (EPA, 1995e).

Around 90 percent of independent PWB manufacturers are small- to medium-sized businesses with annual sales under $10 million, but these shops only account for 20 to 25 percent of total U.S. sales (EPA, 1995e). Conversely, about seven percent of PWB manufacturers are larger independent shops with annual sales over $20 million, but these shops account for about 55 to 62 percent of total U.S. sales (EPA, 1995e).

Currently, rigid multi-layer boards dominate the domestic production value of PWBs, accounting for approximately 66 percent of the domestic market (EPA, 1995e). Double-sided boards account for about one quarter of the domestic market, with single-sided and flexible circuits making up the remainder. The market for multi-layer boards was about $3.4 billion in 1993, up from approximately $700 million in 1980 (EPA, 1995e).

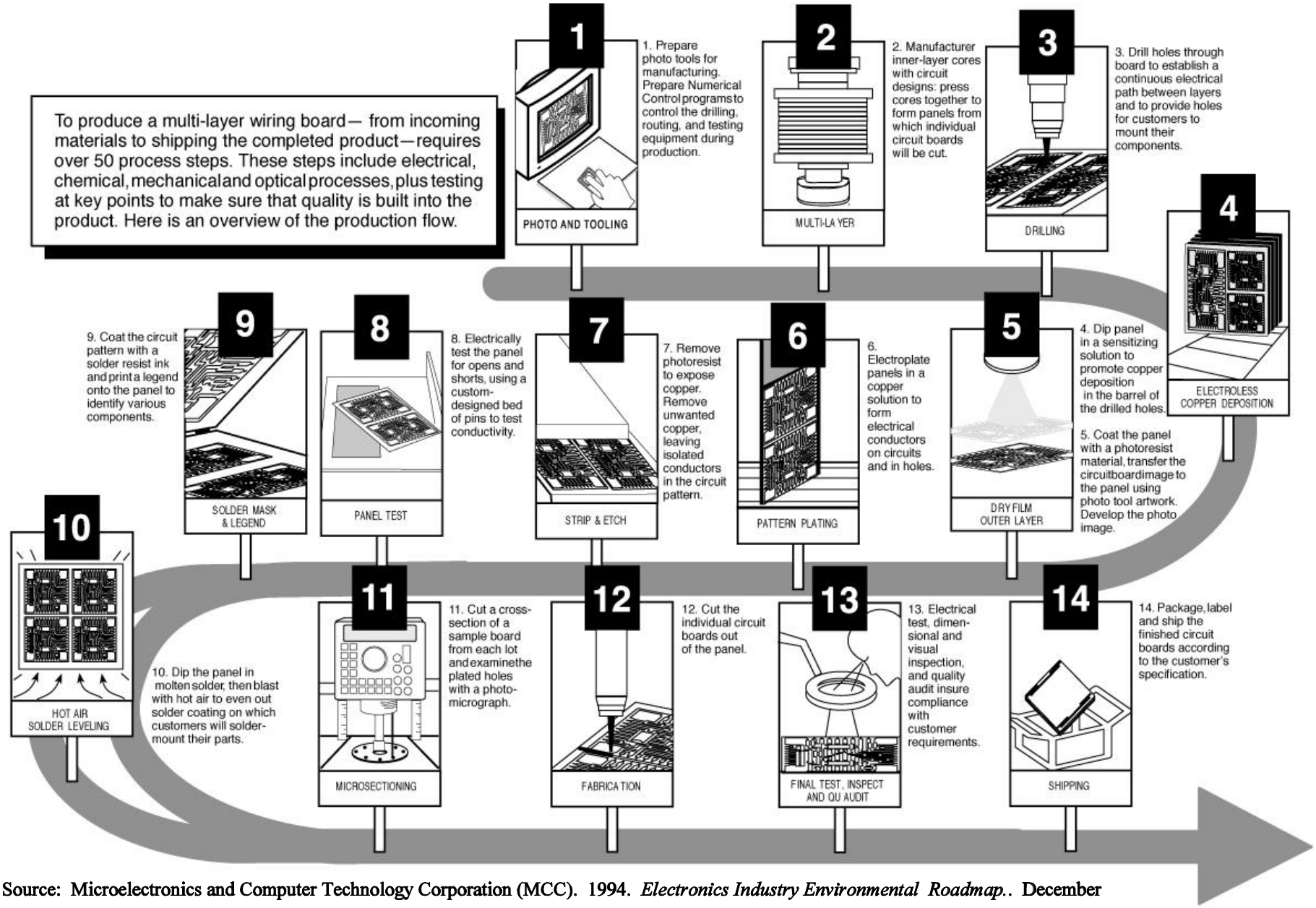
The PWB industry directly employs about 75,000 people, with about 68 percent of employment in production jobs. This is the highest ratio of production jobs for U.S. electronics manufacturing (EPA, 1995e). Additional jobs related to the industry are generated by PWB material and equipment suppliers and the OEMs that produce PWBs for internal use. Further information about the industry may be found in *Printed Wiring Board Industry and Use Cluster Profile* (EPA, 1995e).

1.2.3 Overview of Rigid Multi-Layer PWB Manufacturing

Multi-layer boards consist of alternating layers of conductor and insulating material bonded together. Holes are drilled through the boards to provide layer-to-layer connection on multi-layered circuits. Since most rigid PWB substrates consist of materials that will not conduct electricity (e.g., epoxy-resin and glass), a seed layer or coating of conductive material must be deposited into the hole barrels before electrolytic copper plating can occur. The MHC technologies evaluated in this report are processes to deposit this seed layer or coating of conductive material into drilled through-holes prior to electroplating. Traditionally, this has been done using an electroless copper technology to plate copper onto the hole barrels.

PWBs are most commonly manufactured by etching copper from a solid foil to form the desired interconnect pattern (subtractive processing). Another processing method, called additive processing, is used to selectively plate or metallize a board by building the circuits on catalyzed laminate with no metal foil on the surface. Additive processes to make multi-layer boards have only recently been under development in this country, and none are in widespread use (EPA, 1995e). Figure 1.1 illustrates the basic steps to fabricate rigid, multi-layer PWBs by subtractive processing.

Figure 1.1 Rigid, Multi-Layter PWB Manufacturing Process Flow Diagram



Source: Microelectronics and Computer Technology Corporation (MCC). 1994. *Electronics Industry Environmental Roadmap.*. December